

SECTION 13—NUCLEAR SYSTEMS TECHNOLOGY

13.1	Fissions Reactors	13-3
13.2	Nuclear Materials Processing	13-5
13.3	Nuclear Weapons	13-7

OVERVIEW

This section explains technologies associated with producing and using nuclear fission or fusion energy for both peaceful and military applications. Included are technologies for processing man-made fissile materials, for processing and handling highly radioactive and corrosive materials, for producing plutonium and tritium in reactors, for producing and assembling nuclear weapon components. Technologies for fissile materials enrichment, inertial and magnetic confinement fusion and nuclear related materials are not considered militarily critical.

SECTION 13.1—FISSION REACTORS

OVERVIEW

Key technologies for developing, building, and operating nuclear fission reactor systems include fuel fabrication techniques, critical instrumentation, and control technologies. Of particular interest are space-based and naval nuclear reactors for propulsion. Specifically included in this section are technologies for reactor systems, naval nuclear propulsion, mobile portable and space power and propulsion systems, and electronuclear breeders.

Table 13.1-1. Fission Reactors Militarily Critical Technology Parameters

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
NAVAL NUCLEAR PROPULSION SYSTEMS	Light-water reactors with HEU cores; small high-flux cores; light, small containment vessels; very quiet pumps. Power output not included.	<ul style="list-style-type: none"> • HEU • Zirconium metal and alloys • Hafnium metals²³⁹ 	<ul style="list-style-type: none"> • Radiation-resistant pressure vessels and components • > 36-in i.e. high pressure valves (> 6.9 MPa or 1000 psi) • Quiet pumps, reduction gearing. 	<ul style="list-style-type: none"> • Software bench-marked against operating naval nuclear reactors 	NDUL 2.9 NDUL 2.16 WA ML 17
MOBILE PORTABLE AND SPACE POWER AND PROPULSION SYSTEMS	Power level at output bus able to support appropriate equipment - not included.	<ul style="list-style-type: none"> • ²³⁹Pu in quantities > 1 gm • ²³⁷Np • HEU for reactor cores • Pyrolytic graphic coated fuel particles • Other short-lived heavy isotopes decaying principally via alpha emission 	<ul style="list-style-type: none"> • High temperature (> 450 °C) radiation-resistant reactor control systems. • Efficient <i>Seebeck</i> effect materials for converting isotope decay heat to electricity directly. 	None identified	WA ML 17

(Continued)

Table 13.1-1. Fission Reactors Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
ELECTRO- NUCLEAR BREEDER	500–900 MeV proton accelerators with current in the milliamp range. Spallation neutron production target which can be cooled to withstand operating temperatures or which uses circulating liquid metal. Ability to manufacture tritium at a rate sufficient to accumulate isotope at a rate equal to or greater than the rate of production (or refilling) of weapons.	<ul style="list-style-type: none"> Fuel element fabrication materials: uranium, thorium, zirconium alloys, hafnium-free zirconium Boron for neutron absorption Lithium for breeding tritium. 	<ul style="list-style-type: none"> High-current linear accelerator, probably using superconducting cavities Microwave power systems capable of supporting the high levels of beam power Remote handling equipment (similar to that for other reactors) Equipment for fabricating targets to produce tritium, ²³³U, and transuranic targets. Refueling equipment and reprocessing facility. Handling and extraction facilities for tritium. Ideally, refueling equipment should be able to shift fuel/blanket elements and extract material without lengthy shutdowns. 	Fine grid 3-dimensional simulations of a sub-critical reactor where fission chains are maintained by an external and non-isotope neutron source	NDUL 8.2 NDUL 8.4 NDUL 2. 4 NDUL 2.10 NDUL 2.16

SECTION 13.2—NUCLEAR MATERIALS PROCESSING

OVERVIEW

Handling and processing nuclear materials involves experimentally producing radioactive isotopes, producing weapons-grade and reactor-grade materials, reprocessing spent fuel, and handling transuranic wastes. Technologies of concern include those required for processing and handling highly radioactive and corrosive materials and for producing, handling, and transporting tritium, uranium-233 (^{233}U), and the transuranic elements. The critical technologies identified include tritium production and processing and spent fuel reprocessing.

Table 13.2-1. Nuclear Materials Processing Militarily Critical Technology Parameters

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
URANIUM ENRICHMENT	<ul style="list-style-type: none"> Ability to enrich to > 90% ^{235}U. Ability to manufacture ton quantities of UF_6. Quantity not included. 	<ul style="list-style-type: none"> High-purity fluorine Maraging steel for centrifuges Sintered nickel for gaseous diffusion 	<ul style="list-style-type: none"> Special valves and seals for handling UF_6; lining material for piping Pumps for uranium hexafluoride at high pressure Disposal equipment/site for depleted UF_6 Laser isotope separation equipment 	None identified	NDUL 2.4 NDUL 2.9 NDUL 2.16
TRITIUM PRODUCTION AND PROCESSING	Ability to make tritium at rate corresponding to fill or refill of weapons	<ul style="list-style-type: none"> Pure mercury for lithium enrichment Lithium isotopically enriched in ^6Li Platinized catalysts specially designed or prepared for promoting hydrogen isotope exchange between hydrogen and water for recovering ^3H from heavy water or for producing heavy water Helium isotopically enriched in ^3He. 	None identified	None identified	NDUL 2.10 NDUL 8.5 NDUL 8.6

(Continued)

Table 13.2-1. Nuclear Materials Processing Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
SPENT FUEL REPROCESSING (PLUTONIUM PRODUCTION) <ul style="list-style-type: none"> SOLVENT EXTRACTION OF URANIUM OR TRANSURANICS FROM SPENT RADIOACTIVE FUEL. 	Total weight not included.	<ul style="list-style-type: none"> Large quantities of pure reagents for PUREX or other extraction processes Chemicals for reducing of actinide oxides to pure metals 	<ul style="list-style-type: none"> Remote, unattended or automated equipment for processing irradiated fuel. Shielded casks to transport radioactive material (>1000 kg). Personnel radioactive materials discrimination and diversion detection systems. High-density/lead glass radiation shielding windows > 0.09 m² (1 ft²), with density > 3 g/cm³ and thickness of ≥100 mm (4 in.) and specially designed frames. Radiation-hardened TV cameras rated to withstand 5 x 10⁴ grays (silicon) Fuel chopping machines Reactor discharge equipment and interim cooling facilities for spent fuel. Gaseous diffusion, centrifuge and EMIS equipment for enriching uranium. 	Software unique to the specific processes or equipment in use on an industrial scale.	NDUL 8.2 NDUL 1.6

SECTION 13.3—NUCLEAR WEAPONS

OVERVIEW

If sufficient highly enriched uranium is available, it is probably impossible to preclude construction of a gun-assembled nuclear explosive; therefore, the technologies of concern are those that enable the development of an implosion-assembled device. An implosion-assembled device uses conventional high explosive to strongly compress fissile material into a supercritical assembly. Inertia slows the system disassembly long enough for substantial energy release from fissions. A more advanced weapon development may use the energy from the fission explosion (the primary) to ignite a thermonuclear explosion (the secondary). An even more advanced development may use a mixture of deuterium and tritium in the primary to improve some of its characteristics (a technique called boosting). Critical are technologies developed and applied in the production of nuclear weapons, such as thin-film hydriding; material processing and fabrication techniques; isostatic and hydrostatic pressing; and nondestructive evaluation and imaging. This section also covers safing, arming, fuzing, and firing (SAFF) components and fabrication techniques for uncommon materials or structures, along with some chemical, mechanical, and explosives engineering used in the U.S. nuclear weapons program. Also covered are technologies for developing, producing, and using techniques and devices that enhance nuclear weapon survivability, weapon safety, and other security-related items.

Table 13.3-1. Nuclear Weapons Militarily Critical Technology Parameters

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
NUCLEAR WEAPONS TESTING	<ul style="list-style-type: none"> – Nuclear Test Ban Treaty – Ultrashort pulse/ultra high intensity X-ray source duration < 5 ps; intensity 5×10^{18} w/cm² 	<p>See Nuclear Materials quantity and size (Table 13.2-1)</p> <p>None identified</p>	<ul style="list-style-type: none"> • Flash X-ray generators or pulsed electron accelerators with a peak energy of 500 keV or more. • Single and multiple-axis radiographic test facilities with associated high explosive containment chambers capable of withstanding a conventional explosion with at least as much high explosive as is used in US weapons. • Vertical drilling equipment capable of boring large diameter (> 1.33 m) to depths of 500 m or more. • Mechanical framing cameras with rates > 225,000 frames/s or streak cameras with speeds > 0.5 mm/μs; electronic streak or framing cameras with 50 ns or better resolution. 	Not included	<p>NDUL 5.1</p> <p>NDUL 1.8</p> <p>NDUL 1.4</p> <p>NDUL 7.1</p>

(Continued)

Table 13.3-1. Nuclear Weapons Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
NUCLEAR WEAPONS TESTING (CONTINUED)			<ul style="list-style-type: none"> • Computers having a CTP of 71500 MTOPS • Non modular analog oscilloscopes with bandwidth of 1 GHz or greater; • Plug in modular oscilloscopes with bandwidths of 4 GHz or greater; • Analog sampling oscilloscopes with bandwidths greater than 4 GHz; • Digital oscilloscopes with greater than 1 gigasample/sec, 8 bits or better resolution and 256 or more samples per channel. 		
NUCLEAR WEAPONS PRODUCTION	Not included	<ul style="list-style-type: none"> • Beryllium, beryllium alloys (containing more than 50% beryllium by weight), beryllium compounds (especially oxide), and beryllium parts, waste, and scrap except Beryl (silicate of beryllium and aluminum) in the form of emeralds or aquamarines • Tritium and its compounds, and mixtures containing tritium • Deuterium • Plutonium (fissile material) • High-explosive substances or mixtures containing more than 2% of Cyclotetramethylenetetranitramine (HMX); or Cyclotrimethylenetrinitramine (RDX), or Triaminotrinitrobenzene (TATB); Hexanitrostilbene (HNS); or any greater than 1.8 g/cm³ explosive with greater than 8000 m/sec detonation velocity 	None identified	Not included	NDUL 2.2 WA IL Cat 1 NDUL 8.3 NDUL 2.1 WA IL 1 NDUL 6.4 WA ML 8 NDUL 2.5 NDUL 2.11 NDUL 2.3

(Continued)

Table 13.3-1. Nuclear Weapons Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
NUCLEAR WEAPONS PRODUCTION (CONTINUED)		<ul style="list-style-type: none"> • Calcium (high purity) containing both < 0.001% by weight of impurities other than magnesium and < 10 parts per million of boron • Magnesium (high purity) containing both < 0.0002% by weight of impurities other than calcium and < 10 parts per billion of boron • High-purity (99.99% or greater) bismuth with very low silver content (< 10 parts per million) • Boron and boron compounds, mixtures, and loaded materials in which the 10B isotope is more than 20% by weight of the total boron content. • Uranium in any form 			
NUCLEAR WEAPON COMPONENTS	<ul style="list-style-type: none"> • High-explosive and detonation systems in arrangements using single or multiple precision electrical detonators designed for nuclear weapons. • Optical fibers developed and fabricated to transmit a high-energy pulse from a laser to a high explosive initiator. • Capacitors with voltage rating > 1.4 kV, energy storage > 10 J, capacitance > 0.5 μF, and series inductance < 50 nH, or voltage rating > 750 V, capacitance > 0.25 μF, and series inductance < 10 nH. 	None identified	None identified	None identified	NDUL 6.1 NDUL 6.2 NDUL 6.2.1 NDUL 6.2.2 NDUL 6.3 NDUL 8.1

(Continued)

Table 13.3-1. Nuclear Weapons Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
NUCLEAR WEAPON COMPONENTS (CONTINUED)	<ul style="list-style-type: none"> • Cold cathode tube switching devices with anode peak voltage rating of > 2.5 kV; anode peak current rating of 0.1 kA; anode delay time of 10 μs or less • Fast switch assemblies with a fast function anode peak voltage rating > 2 kV; anode peak current rating of 0.5 kA or more; turn-on time of 1 μs or less • Modular electrical pulse generators capable of: Delivering their energy in < 15 μs; Output > 0.1 kA; Risetime < 10 μs into loads of < 40 ohms; No dimension > 25.4 cm (10 in.); Weight < 25 kg (55 lb) • Triggered spark gaps having an anode delay time of 15 ms or less and a peak current of 0.5 kiloamp or more • Neutron generator systems and accelerator tubes used to initiate nuclear weapons 				